

NON-INVASIVE BLOOD FLOW MONITORING ON THE WRIST

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Abstract- Blood flow changes was measured by PPG in vitro and in patients utilizing a new custom designed optical sensor. The results indicate that the sensor may monitor central related blood pressure variations and congestive heart failure. **Keywords** -Photoplethysmography, light reflection, radial artery, red blood cell orientation

I. INTRODUCTION

Measurements of light reflection in moving blood in vitro give information about the orientation and movement pattern of red blood cells in a circular conduit, being a simple model of a human vessel. The relation between light reflection and shear rate, both in steady flow and pulsatile flow conditions, reflects specific scattering characteristics correlated to the orientation of red blood cells.

The purpose of this study was to present and validate a technique and a sensor for monitoring of blood flow changes over the radial artery.

II. METHODOLOGY

A. Photoplethysmography

Photoplethysmography (PPG) is a common non-invasive method mainly used to measure blood oxygenation level, heartbeat and changes in blood flow [1]. The PPG signal also contains information about the circulatory dynamics [2] and respiratory rate and volume [3]. Principally the method utilizes light reflection and scattering in tissue. The skin or organ is illuminated by radiation in the range of 600 to 1300 nm. The reflected or transmitted light is recorded by a photodetector and variations in light intensity are caused by changes in flow and pressure pulsations in blood. The mechanism behind the origin of the PPG signal are not fully understood. Both red blood cell orientation and volume changes are important factors behind the generation of the PPG signal.

B. In vitro experiments

Experiments were performed on blood circulating in a silicone tubing system described earlier [4]. A waveform generator regulated a roller pump, which produced a simulated pressure waveform resembling the human pulsatile blood pressure. A flow-through hole ($\varnothing=2\text{mm}$) was drilled in a piece of acrylic glass. In reflection mode an optical glass fibre was placed adjacent to the illuminating fiber with a center to center distance of 2.5 mm. The light from the detecting fiber was guided to a silicon photodetector. A light emitting diode (LED, wavelength=880 nm) was used as the light source.

C. Human experiments

Blood flow was measured using PPG on the wrist on heart failure patients. Invasive blood pressure was measured in the contralateral radial artery. A custom designed optical sensor was attached over the radial artery with the optical module slightly curving into the tissue when the sensor was secured with a Velcro closing.

III. RESULTS

A. In vitro experiments

Figure 1 demonstrates relative changes in the AC signal of light reflection (RAC) versus relative changes in pulsatile blood pressure when measurements were performed on blood from 12 healthy blood donors in vitro. The correlation coefficient was 0.95 and the corresponding correlation coefficient when plotting the absolute values of reflection against pressure was 0.82.

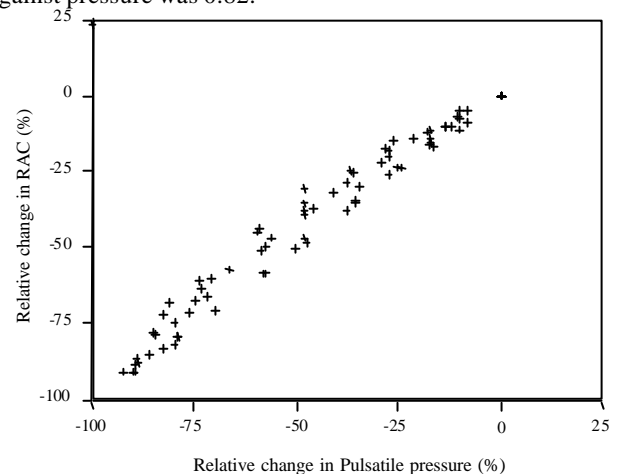


Figure 1 Relative changes in RAC versus blood pressure variations.

B. Human experiments

Figure 2 shows a typical PPG recording on a healthy male subject at rest.

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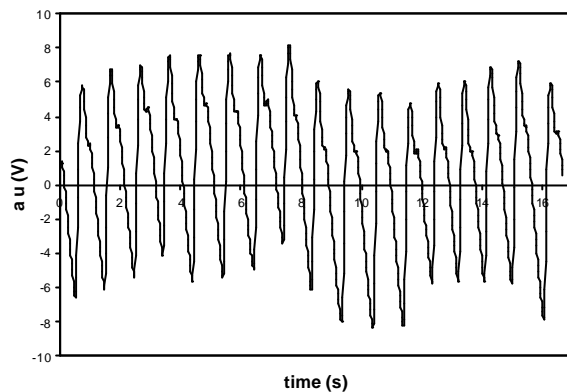


Figure 2 A typical PPG recording on a healthy male subject at rest. The slow variation is due to breathing.

IV. DISCUSSION AND CONCLUSION

According to figure 1 there is a close linear relationship between changes in light reflection and changes in pulsatile blood pressure. This means that, despite substantial variations in the haemoglobin concentration ($Hb=116-162$), which certainly affects the blood viscosity and therefore the orientation capability of the red blood cells, there is a correlation between the pulsatile optical signal and the pulsatile pressure.

A non-invasive sensor for central related blood flow monitoring has been developed. Variations in signal amplitude may reflect different physiological events corresponding to blood pressure variations and congestive heart failure.

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